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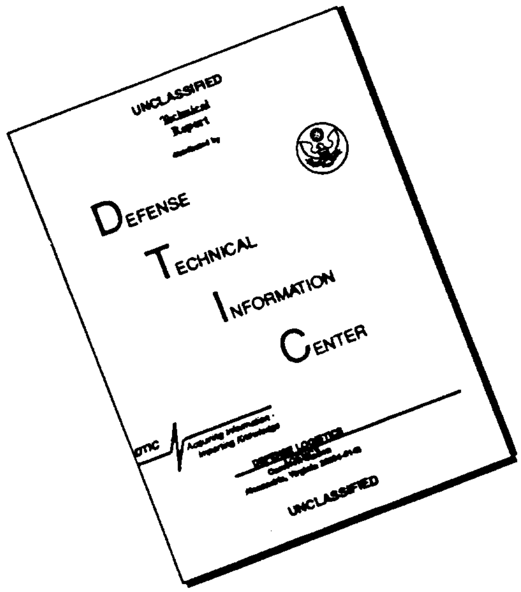

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A RADIATION DOSE INTEGRATOR OF HIGH SENSITIVITY

By Gerhard Dessauer, Kenneth E. Davis, and Fred A. White

INTRODUCTION

The radiation dose integrator described here was designed and constructed to serve as a radiation monitoring unit of high sensitivity and wide application. It differs from the Victoreen integron in being up to 100,000 times as sensitive, and self-resetting.

By suitable adaptation of the specially designed ionization chamber, the unit can be calibrated to measure neutron and gamma radiation in the range from tolerance doses (at tolerance rate) to large doses (fluxes of hundreds of r units per hour).

In addition to this wide range of sensitivity the integrator has the following advantages:

1) AC operated
2) High stability and reproducibility
3) Dual counting and resetting controls
4) Self-recording
5) Ease in mobility of ionization chamber and control units

INTEGRATOR CIRCUIT

The circuit, as shown in Figure 1, is a direct-coupled amplifier consisting of four stages. The first stage utilizes an FP-54 tube whose grid is connected directly to the center electrode of the ionization chamber. The second and third stages are respectively one of voltage amplification using a 6J7, and one of power amplification using a 6L6. The final stage consists of an FG-17 thyratron which provides the relatively large currents necessary to operate the counters and reset relay.

To minimize (1) the need of many bias batteries, and (2) difficulties of instability and drift inherent in direct-coupled circuits, separate regulated power supplies were provided for each stage. The regulator circuit for the FP-54 filament supply is essentially that developed by Dr. T. Enns.

The ionization chamber wall is maintained at a high negative voltage with respect to the FP-54 filament. With the FP-54 grid biased at $-2\frac{1}{2}$ volts, the FG-17 grid bias is -100 volts. If the FP-54 grid is allowed to float, ionization in the chamber will cause this grid to assume a more negative value; when it has assumed a -7 volt bias, the FG-17 will fire (approximately -4 volt thyratron grid bias). The counters will then record and the reset relay will bring the grid of the FP-54 back to $-2\frac{1}{2}$ volts and the cycle will be repeated. The thyratron will be extinguished by its AC plate bias as soon as the reset relay causes the thyratron grid to become -100 volts.

The large voltage swing of the FG-17 grid greatly reduces any error of counting due to slight variations in firing voltage, such as fluctuations due to temperature, etc.

The 110-volt argon pilot serves both as a counting indicator and as a voltage drop for the sensitive reset relay. Moreover, it serves the function of delaying the reset relay until the recording counter has tripped.

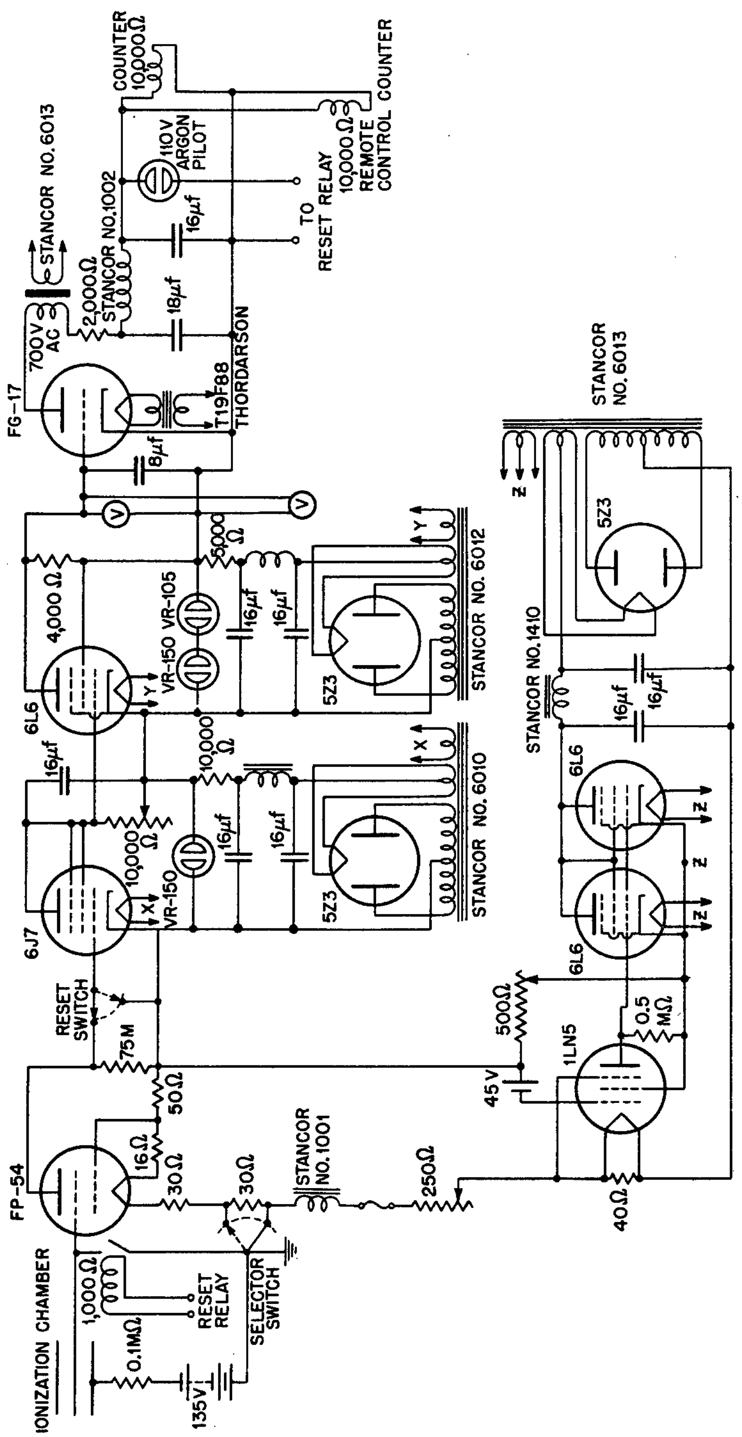

Figure 1. Integrator circuit diagram.

The reset switch is of a momentary contact type which uncouples the FP-54 circuit and places a zero bias on the 6J7, causing the FG-17 to fire and resetting the circuit for a new cycle. Actually, two reset switches were used, one for the main unit, and one for the remote control box. In addition, in each of these units, a voltmeter was inserted to indicate the -100 to -4 volt swing of the thyratron grid. While the amplification of the circuit is not linear, this voltage reading (or rate of drift type reading) can be calibrated for the measurement of very weak radiation fields. This is possible because of the very low grid leakage currents of the FP-54 tube. In the region between -7 and $-2\frac{1}{2}$ volts grid bias, the grid current is of the order of 10^{-15} amps.

If a faster counting rate is desired, the starting grid bias may be made to be any intermediate value between $-2\frac{1}{2}$ and -7 volts. Two counting rates have been set as shown on the circuit diagram with voltage swings of $-2\frac{1}{2}$ to -7 and -4.75 to -7. Choice of counting rate can then be made by means of the selector switch indicated at the ground point in the diagram.

A time delay device (Amperite 115NO45) not shown, is in series with the primary of the thyratron plate transformer to insure adequate warming up of the tube.

The greatest source of error in the integrator is the time lag of the reset relay which is 0.3 second. During this interval the charge collected on the center electrode of the ionization chamber will be drained to ground. For counting rates of 1 count per 30 seconds this error is 1%, for slower counting rates the error is proportionately smaller; however, for fast counting rates, this "dead" time must be accounted for by either a correction, or a proper calibration. If it is desired, the counting rate can be varied within wide limits by proper modification of the ionization chamber which will now be described.

IONIZATION CHAMBER

The ionization chamber (Figure 2) consists of a 3-inch diameter, 1/8-inch wall thickness, and dural tubing which houses two concentric Lucite cylinders whose adjacent surfaces are coated with Aquadag. The Lucite cylinders (as shown in Figure 4) are separated by 1/4-inch. The inner cylinder is threaded on to a polystyrene disc (at the base of the chamber), which is in turn threaded on to the dural base cap which in itself serves as a guard ring for the high negative potential.

The method of insulating and high pressure sealing is similar to that described in another report on a high pressure chamber used in measuring neutron flux.

An exceedingly wide range of sensitivities can be covered by proper adjustment of the following three variables:

1) Capacity: The center (collecting) electrode may be easily replaced by other cylinders of various diameters or by brass rods. The capacity, using a 1/8-inch diameter brass rod, (Figure 3), was found to be 1.45 $\mu\mu$f; with the $2\frac{1}{4}$-inch diameter Lucite cylinder (Figure 4), the capacity was 31 $\mu\mu$f. The capacity can easily be changed by a factor of 100.

2) Type of gas: For neutrons, hydrogen gas is used; for gamma radiation, a gas of high atomic number.

3) Gas pressure: The ionization chamber can be easily evacuated and filled with any gas up to pressures of 250 lb/in^2. A small yoke fits over the neck of the dural chamber so that it can be filled conveniently from any commercial gas tank.

The counting rate is limited only by the mechanical and electromagnetic lags of the counters and reset relay and by the very small leakage currents of the FP-54 grid and ionization chamber. The integrator has been found to have a reliable counting rate between 1 count/3 seconds and 1 count/5 minutes, a ratio of 1 to 100.

For the measurement of neutron fluxes, the integrator can operate within the following limits:

Least sensitivity: 0.2 n/count

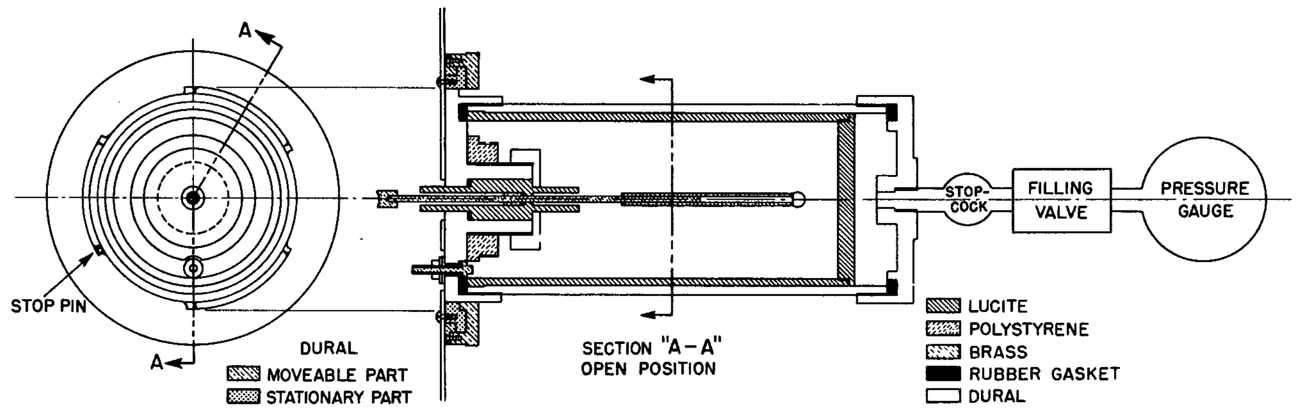

Figure 2. Assembly drawing of ionization chamber.

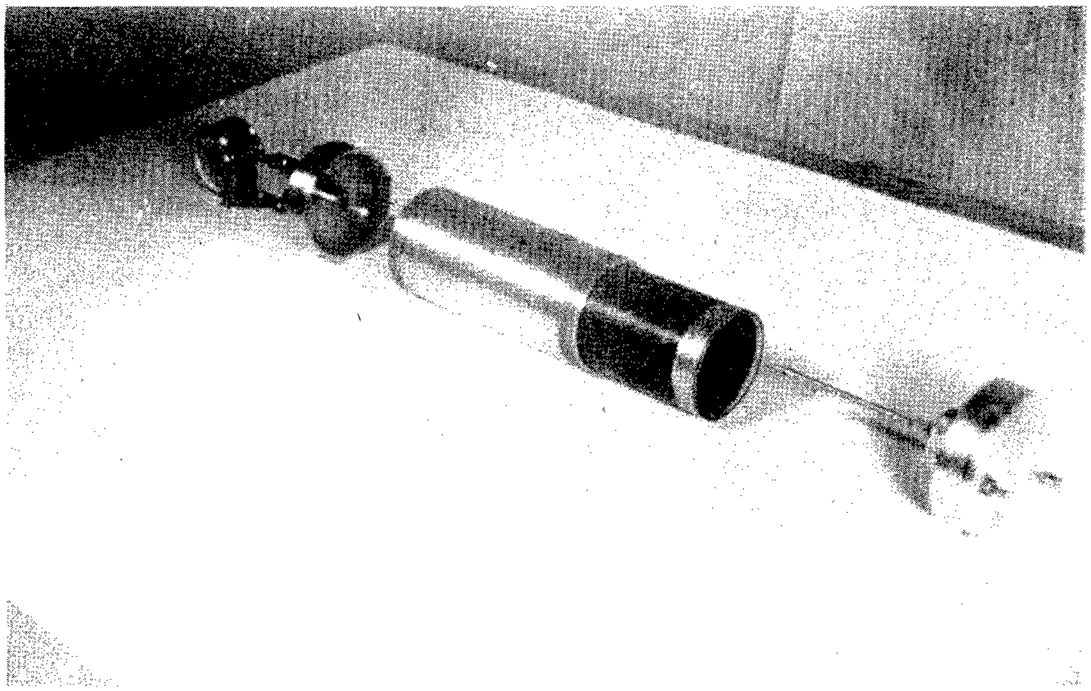

Figure 3.

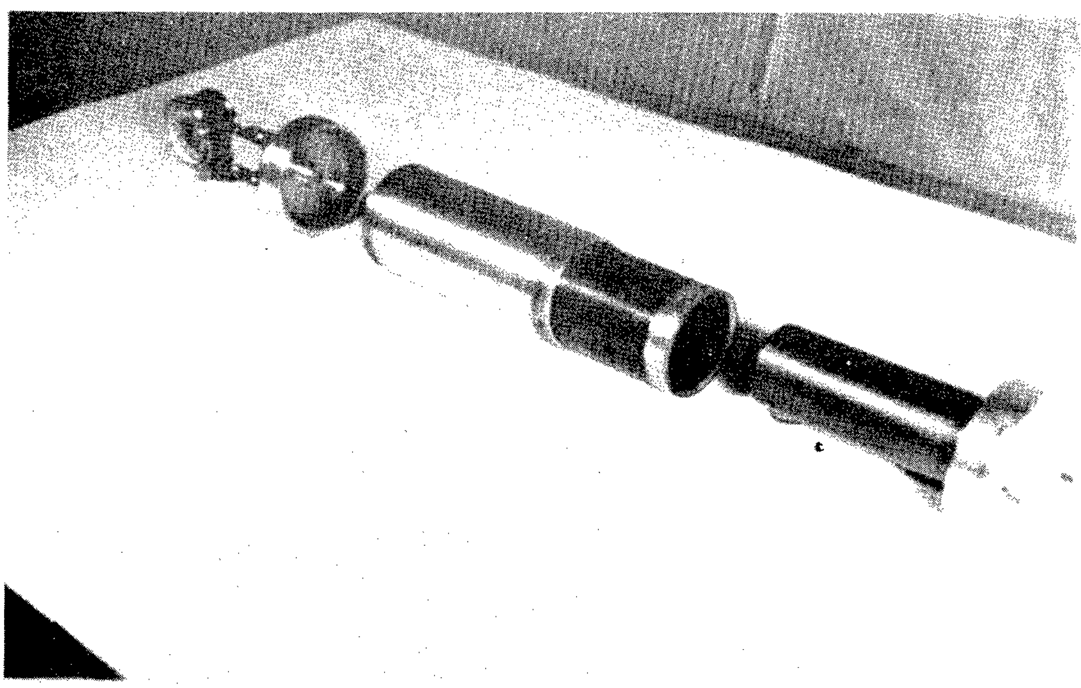

Figure 4.

This can be increased by:

100 x by decreasing capacity
10 x by increasing gas pressure
2 x by changing FP-54 starting grid bias from -2.5 to -4.75 volts.

Greatest sensitivity: 10^{-4} n/count

Since the fastest reliable count is 1 count/3 seconds, the largest measurable flux is: 4n per minute.

Since the slowest reliable count is 1 count/5 minutes, the smallest measurable flux is: 2×10^{-5}n per minute.

A sample set of conditions for monitoring was found to be:

Time of exposure to neutron flux	3 minute
No. of counts	52
Capacity	1.45 $\mu\mu$f
Pressure (hydrogen)	205 lb/in^2 above atmospheric
Sensitivity	2×10^{-4}n/count

PHYSICAL ARRANGEMENT

For flexibility, the integrator has been assembled in three units (Figure 5). The box to which the ionization chamber is fixed (see Figure 5, right, and Figure 6) contains the FP-54 tube, silica gel dryer, resistors, reset relay, the two small $67\frac{1}{2}$ volt ion chamber, batteries, and the 45 volt battery used in the FP-54 power supply. The large cabinet houses the remainder of the circuit elements. The remote control box (left, Figure 5) contains only the duplicate voltmeter, counter, and reset switch with cable socket connection to the main unit.

The ionization chamber itself is held on to the FP-54 box by a special locking mechanism that facilitates easy removal; the center electrode and high voltage contact are of a spring type. The interior view of the FP-54 box (Figure 7) shows these contacts, the tube, and the reset relay. The reset relay grounds the tube grid lead by a platinum to platinum wire contact to eliminate spurious "kicks" due to contact potential. The silica gel dryer is contained in the threaded dural cap on the top of the box for easy replacement.

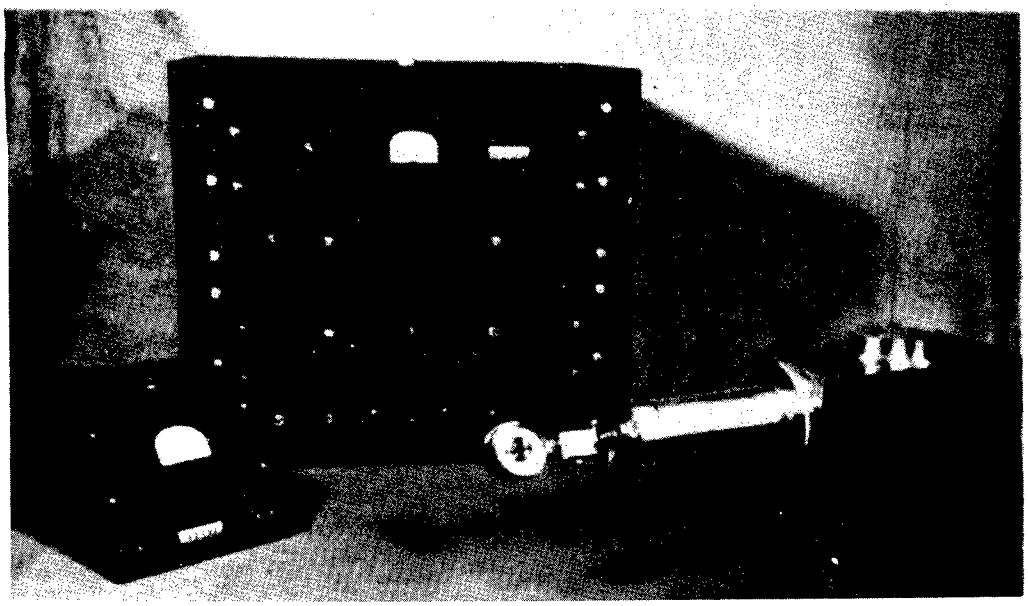

Figure 5.

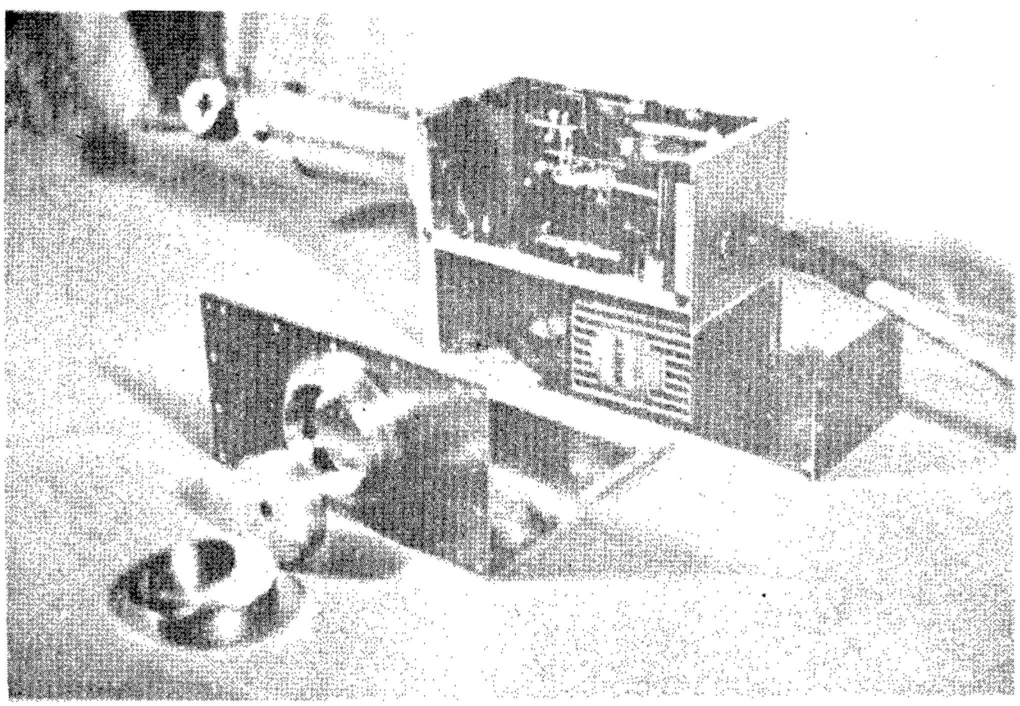

Figure 6.

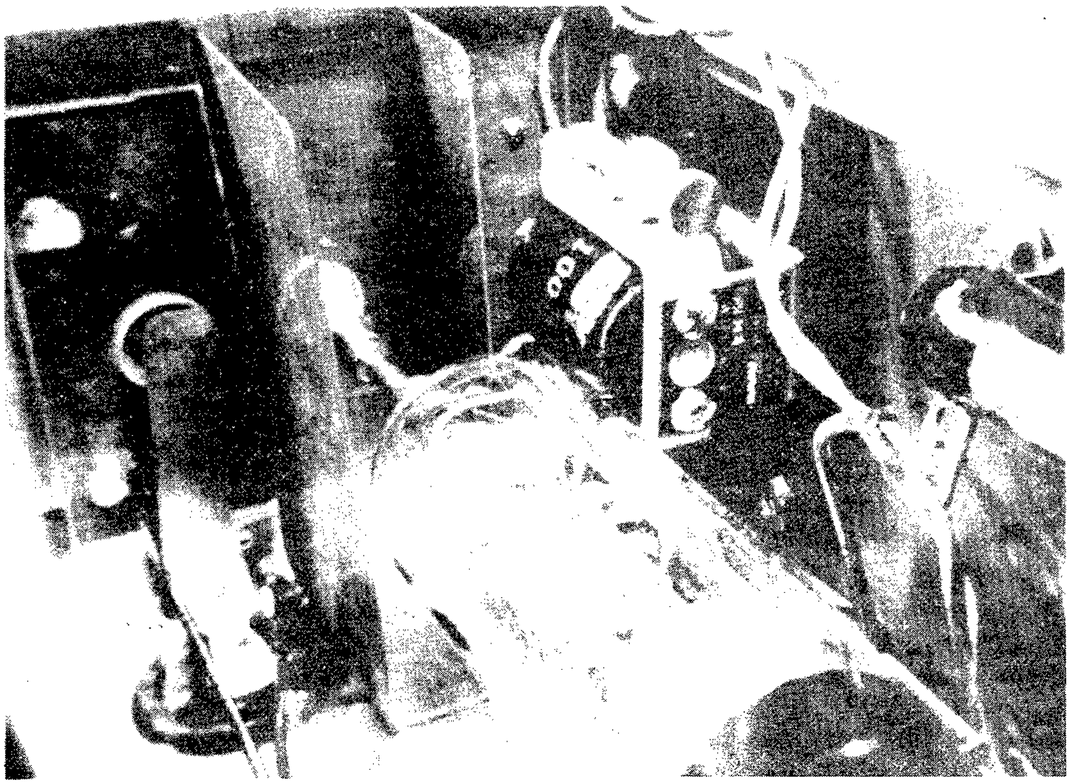

Figure 7.